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Research Article

Classification of Autism Spectrum Disorder for Adolescents Using Artificial Neural Networks

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ABSTRACT

Artificial neural networks, is one of the most preferred artificial intelligence techniques in the modeling of complex systems today and the models are based on the working structure of the nerve cells in the human brain. Autism spectrum disorder is a complex neuro-developmental disorder that is congenital or occurs at an early age. Since early diagnosis has a very important role in the treatment, there are many studies on this subject. In this study, a subset of current autism spectrum disorder data obtained from UCI machine learning repository for adolescents has used. In order to test the success of the model, after the necessary preprocesses have performed on the data set, the data has separated into training and test set and classified with the trained network. As a result, 100% accuracy rate in the training set and 96.77% accuracy rate in the test set are achieved. Sensitivity, Specificity and F-measure values obtained in the test set are 0.94, 1.0 and 0.97, respectively and reveals the model success.

Keywords: Autism Spectrum Disorder, Classification, Adolescent Subset, Artificial Neural Networks

This study was presented as a summary paper at the 6th International Management Information Systems Conference in Istanbul in 2019 and published in abstracts book

1. Introduction

In today's world, programmed computers can collect information about specified events, make decisions and reveal the relationships between events. Thus, it is possible to reach the solution of even complex problems that cannot be solved directly with mathematical formulas. When looking at the subject of the studies on the acquisition of these capabilities to computers, it is seen that they are expressed as studies on artificial intelligence in the most basic sense. Although the history of artificial intelligence studies dates back to the 1950s, it is being developed day by day and used in all areas of life. With the development of artificial intelligence and the increase in its usage areas, the studies have also gained great importance and the studies on artificial intelligence have continued to take place in the literature with a great increase. Artificial Neural Networks (ANN) is a technique that is among the topics of artificial intelligence and is frequently used in subjects such as artificial intelligence and machine learning. It is possible to make predictions about new situations by modeling the relationships between the information collected through ANN. From this aspect, artificial intelligence is one of the most preferred methods in all situations where fast and accurate decisions are required. Marketing, banking, education, web and medicine are just some of these usage areas.

In the literature, there are many studies in which ANN is used for estimation or performance comparison is made. Some of these studies are as follows; Ayaz et al. (2017) classified seven different apricot tree species according to their leaf features with ANN. Canayaz and Demir (2017) studied feature selection process using Whale Optimization Algorithm and ANN. Calp (2019), on the other hand, trained the data obtained from the cafeteria database of a private enterprise that produces daily meals with ANN and made the estimation of the daily food demand. Yıldız and Özdemir (2019) compared the performance of ANN with flexible back propagation algorithm and back propagation algorithm. Yıldırım (2019), on the other hand, estimated house prices by regression and ANN methods using the current real estate data of Adana province. Koçak and Karakurt (2019) used ANN to determine the ideal values for data traffic in wireless local area networks. The feasibility of using ANN for skid operation stations in the eastern Black Sea Region has been investigated by Çalışkan and Sevim (2019).

Especially since health has a very important place in human life, it has been observed that the studies in this field have increased gradually. There are many studies in the literature in which artificial intelligence techniques are used in the field of health. Some of these studies in which ANN is used in the field of health are as follows; Yoldaş et al. (2012) investigated a model that can be used in the diagnosis of appendicitis (AA) in their study, and ANN was used as a method. The laboratory results of 400 patients with 24 qualifications were classified using radial-based functional network (RBFN) and ANN by İlkuçar (2015). On the other hand, Er et al. (2015), one of the prediction methods in their study for the diagnosis of Mesothelioma was ANN. It was studied by Özkan et al. (2016) to automatically identify epilepsy disease using ANN. In another study conducted in the field of health, Çelik et al. (2018) made a classification by performing feature selection on the human spine data set with the adaptive neural fuzzy classifier. Özmen et al. (2018) classified cardiac disease using methods such as ANN and Support Vector Machines, and the

performances of the methods were compared. Çetin and Temurtaş (2019) classified magnetoencephalography (MEG) signals with ANN.

In this study, subjects with autism in recent years, although Turkey and the world is pretty much a disease, early detection in the treatment has a very important place. For this reason, the use of current systems for diagnosis and treatment is increasing and artificial intelligence techniques are integrated into the studies. Some studies on this subject are as follows; Thabtah et al. (2018) emphasized the necessity of using new technologies such as information technologies and data mining in studies with autism, as in many areas, and created a new data set on autism. In order to ensure the validity and reliability of the data set they created, they determined the attributes associated with autism and each other by using the techniques used for autism and data mining techniques. Thabtah (2018) collected ASD data, divided it into subgroups, and classified these data using logistic regression and Naive Bayes methods. Success rates for the adolescent data set were 94.23% and 91.34%, respectively. Akyol and Karaci (2018) made feature selection and classification using the subset of ASD data for children, and logistic regression and fuzzy rule logistic regression were used as methods. Success rates are reported as 97.33%. De Campos Souza and Guimaraes (2018) compared the prediction methods for the mobile application developed by Thabtah (2017) for the prediction of ASD data in the child subclass and stated that the most applicable is the fuzzy neural network architecture.

In this study, an estimation was made with the ANN model, which was trained with the subset of autism data for adolescents, and a classification process was carried out to allow preliminary assessment for individuals who were found to be likely to have autism. Accuracy, Sensitivity, Specificity, F-Measure criteria were used for the performance evaluation of the classification made with the trained network. Although there are several classification studies with the same data set in the literature, such detailed calculations for a classification made with ANN and performance evaluation of the model have not been encountered. From this point of view, the study will provide a more comprehensive perspective to the literature and performance evaluation.

Methods and Data Set

In this study, the ANN method was used because it gives better results than other methods and the results are given.

Artificial Neural Networks have been developed based on modeling the way the brain functions (Karahan, 2015) . There are many biological neural networks in the human brain and the brain performs its functions through these networks (Akkaya, 2007). Nerve cells (neurons) constitute the basic element of biological neural networks working as a system. The nerve cells, which have a working mechanism in themselves, connect to each other and form the neural network. Approximately over a thousand nerve cells in the human brain communicate with each other and work in a way to transmit the information they receive from one cell to other nerve cells. When looking at the basic elements of a nerve cell, it is seen that the cell body, dendrite and axon (Koç et al. 2004). The image of the biological nerve cell is given in Figure 1.

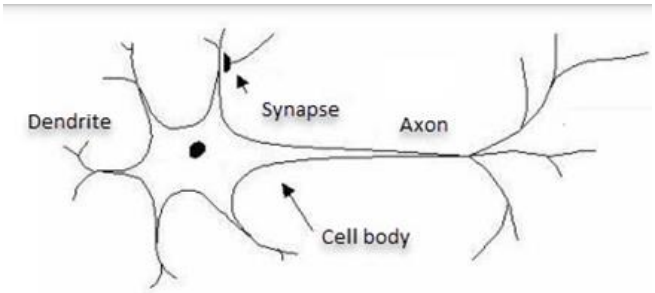

Figure 1. Biological Nerve Cell Image (Koç et al. 2004)

When looking at the working structure of the nerve cells, the function of dendrites is to receive stimuli from another nerve cell and transmit it to the body in the nerve cell where it is located. Changes occur in the chemical structure within the cell with the stimuli from the other cell. Because of these changes, after a number of processes are performed, the task of transmitting the new structure to other nerve cells is given to axons. Synapses are located in the cell body and play a role in providing intracellular transmission. In this process, changes may occur in existing synaptic relationships that interact with stimuli to cells, and new synaptic relationships established are defined as the learning process (Koç et al. 2004).

ANN is mainly based on the idea of mathematical modeling of biological neural networks in a simplified manner (Küçükkocaoğlu et al. 2005). The representative image of the artificial nerve cell is shown in Figure 2.

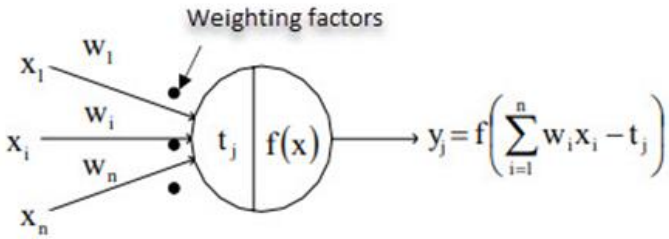

Figure 2. Artificial Neural Cell Image (Koç et al. 2004).

The similarity between biological and artificial nerve cells (Figure 1 and Figure 2), connections between cells (stimuli coming to and from the cell) to axons and dendrites; Weighting factors (wi) are established to correspond to synapses and breakpoints (tj) to intracellular stability. A nonlinear activation function f (x) with its help it is converted to excitations (yj) in the form of output.

While designing the ANN, the connections between cells, that is, the information coming to and from the cell, were compared to dendrites and axons, and the weight factors calculated in the ANN to the synapse structures in the cell body (Kaynar and Taştan, 2009). In the artificial neural cell, the values coming to the cell depending on the effect of the weight factor are obtained as output information with the help of an activation function, taking into account the intracellular balance state (Kaynar et al. 2011). ANN is formed by connecting artificial nerve cells to each other generally in a layered structure (El-Bouri et al. 2000). In ANN, the learning process occurs when the weight factors of the connections established between artificial nerve cells change as a result of recalculation while transmitting (Ekinci et al. 2010). Thus, thanks to ANN, it is possible to solve complex problems by imitating the learning ability of the human brain (Deb et al. 2018). When the ANN models are examined, it is seen

that there are many types of ANN models (Kalogirou, 1999). The ANN model used can be used in many processes such as classification, clustering or estimation according to its intended use (Akyılmaz and Ayan, 2010). ANNs have two main classes as feed forward and backfeed ANN according to the network structure and the most widely used model is the feed forward ANN model (Uygunoğlu and Yurtcu, 2006). According to the training algorithms, it is possible to classify them as supervised and unsupervised ANN and the most preferred learning method is supervised.

In this study, the subset of the current Autism Spectrum Disorder (ASD) data for adolescents was used. The data were obtained from the UCI website and the name of the data set is Autistic Spectrum Disorder Screening Data for Adolescent Data Set (Machine Learning Repository,https://archive.ics.uci.edu/ml/datasets/Autistic+Spectrum+Disorder+Screening+Data+for+Adolescent+++, 05.02.2019.). The data set was prepared according to the last accepted parameters for the diagnosis of autism spectrum disorder and its validity has been proven (Thabtah, 2017). The data were collected through the ASDTests application and it was reported to the participants that their information would be shared for research purposes only, with anonymity to whom their information belongs (Thabtah, 2019). In the data set, the input parameters are composed of the demographic characteristics of the participants and the answers to the questions measuring ASD. The test, which was applied to 1100 people in total, was divided into three categories as children, youth and adults, depending on the age range. Although questions involving demographic characteristics are common in groups, questions about behavior differ between age groups. In this study, the subset for adolescents was used and there are 104 samples in this subset. There are a total of 21 attributes in the data set, including the result tag. The data set includes numerical and categorical data types, and there are some missing data. In the data pre-processing process, missing data was completed by arithmetic mean and it was ensured to work with complete data.

Results and Discussion

In the study, a classification process was carried out to identify individuals with probability of autism among adolescents consisting of 104 samples. In the data set, there is an output showing autism status against 20 attributes. The class labels of the outputs are "yes" and "no". For the classification process, feed forward ANN model was used, and the data set was divided into 70% training and 30% test data (Çelik, 2020). Since there are 20 features in the data set used, the input layer of the designed network is 20, because there are 2 classes in the classification to be created, the output layer is 2, and the number of neurons in the hidden layers has been selected as 5 and 5, as the results of the experiments. The model of the designed network is shown in Figure 3.

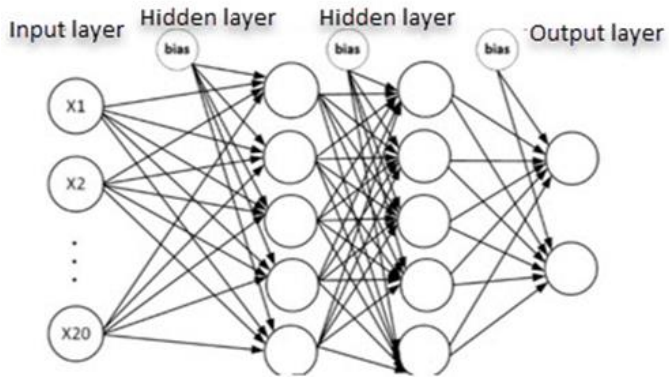

Figure 3. Designed ANN

The compatibility of the input data when trained in ANN is given in Figure 4.

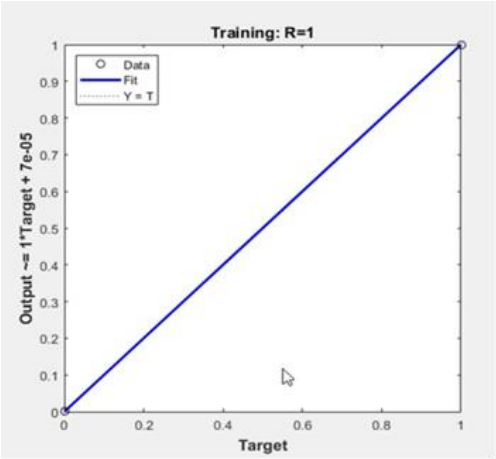

Figure 4. The Compliance of Input Data When Trained in ANN

As seen in Figure 4, the R value is 1. This is a clear indication that the model created fully reflects the training set.

The performance chart of the developed ANN in the training phase is shown in Figure 5.

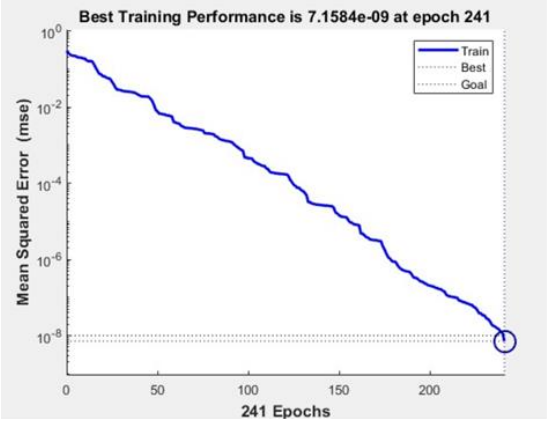

Figure 5. Performance Chart of The Developed ANN in The Training Phase

As seen in Figure 5, as the number of trainings progressed, the error value of the network decreased. This shows that the network is well trained. Performance values of the designed ANN are given in Table 1, and the ROC curve (Receiver Operating Characteristic) for test data is shown in Figure 6.

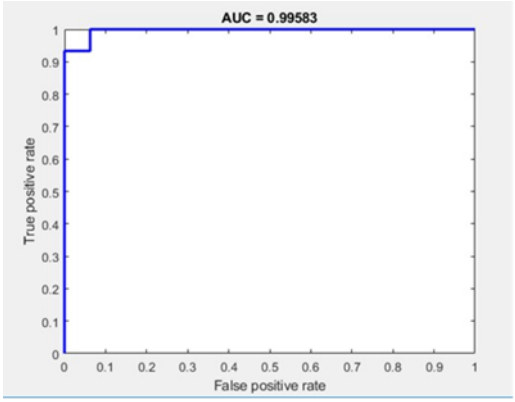

Figure 6. ROC Curve Plotted for Test Data

As seen in Figure 6, the area under the ROC curve (AUC) value has been found very close to 1. This result shows that a high success has been achieved in the classification made in the test data.

Classification details for training and test data are given in Table 1 as Confusion Matrix. A confusion matrix is a table often used to describe the performance of a classification model over a set of test data for which actual values are known. The values used in the table are True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN).

	TP	TN	FP	FN
Training	48	25	0	0
Test	15	15	0	1

Table 1. Confusion Matrix Created for Training and Test Data

As can be seen in Table 1, all data are classified correctly in the training data, and there are no examples of the wrong class. For test data, 30 out of 31 data were classified correctly and only 1 sample was incorrectly classified.

Accuracy, Recall, Specificity and F-Measure values of the ANN model created were calculated as shown in Equation (1), Equation (2), Equation (3) and Equation (4), respectively. TP, TN, FP, FN values used in the calculations in Equation (1-4) are given in Table 1.

$$\text{Accuracy} = ((TP+TN) / (TP+TN+FP+FN)) \quad (1)$$

$$\text{Recall} = (TP / (TP+FN)) \quad (2)$$

$$\text{Specificity} = (TN / (TN+FP)) \quad (3)$$

$$\text{F-Measure} = ((2*TP) / (2*TP+FP+FN)) \quad (4)$$

	Accuracy	Recall	Specificity	F-Measure
Training	%100	1	1	1
Test	%96.77	0.9375	1	0.9677

Table 2. Performance Values of the Designed ANN Model

As seen in Table 2, the success rate of the classified data was 100% in training data and 96.77% in test data.

As it is known, in estimated values, the accuracy of the estimation and the error is inversely proportional. In other words, as the error of the predicted value approaches zero, the accuracy of the model also increases. As can be seen, the success rate is

quite high. This situation shows that the error rates will also be very low. As a result, it is possible to say that the trained model is compatible with the data and the success in the classification is high.

While determining the attributes used in the relevant data set, they used the most up-to-date manual and parameters among the diagnostic criteria used in autism. It has shown that the model developed in the successful results can have an important place in the diagnosis of ASD.

Conclusions

ASD is a congenital or complex disease that occurs at an early age and early diagnosis is of great importance in its treatment. In this study, autism data were classified using the ANN method. Before the classification process, missing data were completed by arithmetic mean and it was ensured to work with complete data. Two hidden layers are used in the designed network. The number of neurons was determined as 5 and 5, respectively. In addition to the classification accuracy percentage of the data in both data sets as training and test data, various metrics were also used to determine the success rate.

When looking at the results, the accuracy was calculated as 100%, Recall = 1 Specificity = 1 and F-Measure = 1 in the training set. In the test set, accuracy was calculated as = 100%, Recall = 0.9375 Specificity = 1 and F-Measure = 0.9677. These results reveal that the success rates are quite high in both training and test data, and the error rates are quite low. Especially the successful results obtained in the test set show that the ANN gives values close to the real results.

Although the successful results obtained on the data set show that the developed model can be used in the early diagnosis of ASD in daily life, theoretical studies involve various difficulties while transforming them into real-time systems. There are questions answered by the users in the relevant data set, and real systems to be designed in the future should be developed considering that the attribute values may not be as stable as in the data set. In this study, it should be considered that the success of ANN, which is run on stable and meaningful features, in real time systems may decrease slightly.

As a result, the necessity of using current techniques in today's studies is obvious and ANN, which is one of the artificial intelligence techniques, is one of them. In addition to learning the complex relationships between data and making generalizations, ANN can find answers with an acceptable error to questions that it has never encountered before, and thus it is used as an effective method for predicting.

In future studies, it is aimed to increase the success rate by using normalization and other pre-processing techniques on the data set or by trying other methods for classification. In addition, a computer-aided application can be developed that can help healthcare professionals.

References

Akkaya, G. (2007). Yapay sinir ağları ve tarım alanındaki uygulamaları. Atatürk Üniversitesi Ziraat Fakültesi Dergisi, 38(2), 195-202.

Akyılmaz, O., & Ayan, T. (2010). Esnek hesaplama yöntemlerinin jeodezide uygulamaları. İTÜDERGİSİ/d, 5(1).

Akyol, K., Karaci, A. (2018). A Study On Autistic Spectrum Disorder For Children Based On Feature Selection And Fuzzy Rule. In: International Congress on Engineering and Life Science, pp. 804–807

Ayaz, F., Ari, A., & Hanbay, D. (2017, September). Leaf recognition based on artificial neural network. In 2017 International Artificial Intelligence and Data Processing Symposium (IDAP) (pp. 1-5). IEEE.

Calp, M. H. (2019). İşletmeler için personel yemek talep miktarının yapay sinir ağları kullanılarak tahmin edilmesi. Politeknik dergisi, 22(3), 675-686.

Canayaz, M., & Demir, M. (2017, September). Feature selection with the whale optimization algorithm and artificial neural network. In 2017 International Artificial Intelligence and Data Processing Symposium (IDAP) (pp. 1-5). IEEE.

Çalışkan, E., & Sevim, Y. (2019). A comparatıve study of artıfıcıal neural networks and multıple regressıon analysıs for modelıng skıddıng tıme. Applıed Ecology And Envıronmental Research, 17(2), 1741-1756.

Çelik, S., Bozkurt, Ö. Ç., & Çeşmeli, M. Ş. (2018). İnsan omurgasi veri setinin sinir-bulanik siniflayici ile öznitelik tespiti ve siniflandirilmasi. Yönetim Bilişim Sistemleri Dergisi, 4(1), 39-52.

Çelik, S., (2020). Determination and classification of ımportance of attributes used in diagnosing pregnant women's birth method. Alphanumeric Journal, 8(2), 261-274.

Çetin, O., & Temurtaş, F. (2019). Görsel uyaranlara ilişkin manyetoensefalografi sinyallerinin genelleştirilmiş regresyon sinir ağı ile sınıflandırılması. Dicle Tıp Dergisi, 46(1), 19-25.

Deb, C., Lee, S. E., & Santamouris, M. (2018).Using artificial neural networks to assess hvac related energy saving in retrofitted office buildings. Solar Energy, 163, 32-44.

De Campos Souza, P. V., & Guimaraes, A. J. (2018, June). Using fuzzy neural networks for improving the prediction of children with autism through mobile devices. In 2018 IEEE Symposium on Computers and Communications (ISCC) (pp. 01086-01089). IEEE.

Ekinci, Y., Temur, G. T., Çelebi, D., & Bayraktar, D. (2010). Ekonomik kriz döneminde firma başarısı tahmini: yapay sinir ağları tabanlı bir yaklaşım. Journal of Industrial Engineering, 21(1), 17-29.

El-Bouri, A., Balakrishnan, S., Popplewell, N. (2000). Sequencing jobs on a single machine: a neural network approach. European Journal of Operational Research, 126, 474–490.

Kalogirou, S. A. (1999). Applications of artificial neural networks in energy systems. Energy Conversion and Management, 40(10), 1073-1087.

Karahan, M. (2015). Turizm talebinin yapay sinir ağaları yöntemiyle tahmin edilmesi. Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 20(2), 195-209.

Kaynar, O., Taştan, S., & Demirkoparan, F. (2011). Yapay sinir ağlari ile doğalgaz tüketim tahmini. Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 25(özel sayı), 463- 474.

Kaynar, O., & Taştan, S. (2009). Zaman serisi analizinde mlp yapay sinir ağları ve arıma modelinin karşılaştırılması. Erciyes Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, (33), 161-172.

Koçak, C., & Karakurt, H. B. (2019). Yapay sinir ağları ile kablosuz yerel alan ağlarında veri trafiği optimizasyonu. Politeknik Dergisi, 22(3), 737-747.

Koç, M. L., Balas, C. E., & Arslan, A. (2004). Taş dolgu dalgakıranların yapay sinir ağları ile ön tasarımı. Teknik Dergi, 15(74), 3351-3375.

Machine Learning Repository, https://archive.ics.uci.edu/ml/datasets/Autistic+Spectrum+Disorder+Screening+Data+for+Adolescent+++, 05.02.2019.

Özkan, C., Doğan, S., Kantar, T., Akşahin, M. F., & Erdamar, A. (2016, May). Detection of epilepsy disease from EEG signals with artificial neural networks. In 2016 24th Signal Processing and Communication Application Conference (SIU) (pp. 693-696). IEEE.

Özmen, Ö., Ahmad, K. H. D. R., & Engin, A. V. C. I. (2018). Sınıflandırıcıların kalp hastalığı verileri üzerine performans karşılaştırması. Fırat Üniversitesi Mühendislik Bilimleri Dergisi, 30(3), 153-159.

Uygunoğlu, T., & Yurtcu, Ş. (2006). Yapay zeka tekniklerinin inşaat mühendisliği problemlerinde kullanımı. Yapı Teknolojileri Elektronik Dergisi, 2(1), 61-70.

Thabtah, F. (2017, May). Autism spectrum disorder screening: machine learning adaptation and DSM-5 fulfillment. In Proceedings of the 1st International Conference on Medical and Health Informatics 2017 (pp. 1-6). ACM.

Thabtah, F. (2017). ASDTests. A mobile app for ASD screening.

Thabtah, F. (2018). Machine learning in autistic spectrum disorder behavioral research: A review and ways forward. Informatics for Health and Social Care, 1-20.

Thabtah, F., Kamalov, F., & Rajab, K. (2018). A new computational intelligence approach to detect autistic features for autism screening. International journal of medical informatics, 117, 112-124.

Yıldırım, H. (2019). Property value assessment usıng artıfıcıal neural networks, hedonıc regressıon and nearest neıghbors regressıon methods. Selçuk Üniversitesi Mühendislik, Bilim ve Teknoloji Dergisi, 7(2), 387-404.

Yıldız, E., & Özdemir, E. (2019). Esnek Geri Yayılımlı ve Geliştirilmiş Geri yayılımlı sinir ağları performanslarının elektrikli ark ocaklarında karşılaştırılması. International Journal of Multidisciplinary Studies and Innovative Technologies, 3(1), 72-75.

Yoldaş, Ö., Tez, M., & Karaca, T. (2012). Artificial neural networks in the diagnosis of acute appendicitis. The American Journal of Emergency Medicine, 30(7), 1245-1247.